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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Lubrication Problems Created by the Modern Diesel

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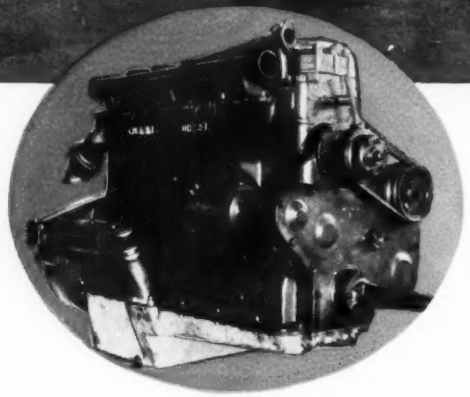

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Lubrication Problems Created by the Modern Diesel

THE principal interest of the Diesel engine designer for the past several years has been the reduction of weight and space requirements brought about by the increased use of the Diesel in submarine, railroad and automotive service. Remarkable strides in this direction have been taken, particularly in the 500 to 1000 H.P. engines in submarine and railroad service, where weight and space are prime considerations. In this type Diesel specific weight figures have dropped from 50 pounds in 1920 to 30 in 1930 and have now nearly reached the low figure of 20 pounds per horsepower. In the automotive field the Diesel has always been at a disadvantage on a weight basis with the gasoline engine, consequently the automotive Diesel manufacturer has utilized every method available to reduce weight and increase power output.

The specific weight, pounds per horsepower, of Diesels has been reduced by speeding up existing engines, by raising operating pressures, by eliminating unnecessary engine weight or by a combination of these improvements. All of these changes have, of course, been accompanied by many alterations in design and some of them have affected lubrication:

1. Higher speeds and smaller engines with smaller oil reservoirs have elevated engine temperatures.
2. Higher ring temperatures have resulted in ring sticking difficulties.
3. Higher engine temperatures, together with higher loads and speed, have necessitated the use of more rugged bearing metals, which in some cases have resulted in oil corrosion difficulties.
4. The newer type bearings coming into general use are more sensitive to solid particles in the lubricating oil, requiring improved oil purification.
5. Lighter, less rigid frames may be contributing to bearing difficulties encountered in certain designs.
6. The decline of air injection in favor of direct injection in the larger engine sizes has increased firing pressures, contributing to greater bearing loads.
7. Replacement of air injection engines by solid injection Diesels has resulted in oil purification problems where heavy fuels are used.
8. Although offset by improved piston ring and cylinder metals, also by special surface treatment, higher speeds and temperatures have made proper cylinder lubrication more difficult.
9. The popularity of two cycle engines has occasioned special study by the lubrication engineer to provide methods for maintaining an oil film under the temperatures encountered when operating under increased power outputs.
10. Supercharging has imposed increased duty on the lubricating oil since it is usually not accompanied by the changes in the lubri-

cating system required to take care of the greater power output.

11. The increased use of copper in some engines has contributed a catalyzing effect promoting oil oxidation.
12. The increased clearance required by aluminum pistons has created oil consumption problems particularly in the larger sizes when operating at part loads.
13. The increased use of Diesels in sub-freezing weather has brought the starting qualities of lubricating oil into the Diesel picture.

OIL TEMPERATURE

To bring about a reduction in specific weight, speeds have been increased so that in proportion to the size of the engine, more heat is produced. At the same time the restrictions imposed on the capacity of the oil and cooling systems has resulted in a reduction of the means for carrying heat away from the engine. In mobile installations this is somewhat offset by air cooling brought about by motion of the power unit but in general engine temperatures have been elevated. One of the worst temperature situations is found in the stationary installation of an engine originally designed for mobile operation without the necessary additional cooling. This often results in engine room temperatures of 120 degrees or higher, due to the radiated heat from the engine.

The effect of the higher oil temperatures has been far reaching. The increased temperature has proven beneficial in many respects as shown by the test results on a high speed Diesel given in Table A.

Table A

EFFECT OF OIL TEMPERATURE ON FUEL ECONOMY

Crankcase Oil Temperature	Friction HP	Fuel Economy, miles/gal.
100	15.0	12.3
150	13.5	12.9
200	12.7	13.5
250	12.4	14.0

In fact, the higher temperature is a necessity in the faster running Diesel to produce the quick ignition of the fuel necessary to complete the combustion process in the shorter interval of time available.

This increased heat, however, is not particularly beneficial to the lubricating oil. While low crankcase temperatures are not desired because of the possibility of condensation of the steam which makes up a high percentage of the blow-by gases, temperatures above 200 degrees Fahr. affect the oil adversely if maintained for any length of time. Heating the oil momentarily to a few hundred degrees does not harm it particularly when it is passing through an oil cooled piston or through a centrifuge where the oil does not come in contact with much air and when exposure to the higher temperatures occurs only for short periods.

Fig. 1—Carbon on underside of piston head due to high crown temperature and improper oil.

The effect of heating an oil under different conditions is shown in Table B.

Table B

TESTS ON NEW OIL AFTER VARIOUS METHODS OF HEATING

	New Oil	New Oil after centrifuging six times at 200°	New Oil after heating for 90 min. at 400 degrees Fahr. and agitated with activated clay	New Oil after heating for 6 hours at 450 degrees and agitated with air
Color	Pale	Pale	Pale	Black
Viscosity, SSU at 210 degrees	58	58	58	69
Precipitation No. (solids)	0	0	Trace	0.06
Neutralization No. (oxidation)	0.04	0.05	0.07	0.60

It is apparent from these results that only prolonged heating in the presence of air (as shown in the last column) may cause oil deterioration.

Oils should not be heated much above 500 degrees even momentarily because of the possibility of cracking which causes the formation of tar and coke. An example of deposits formed due to cracking is the carbon frequently found under the piston head. Cracking temperatures exist under some pistons under full load running conditions and in some engines oil film temperatures will rise to dangerous heights if the engine is not allowed to run a few minutes under light load before shutting down. Auxiliary driven piston cooling and circulating water pumps which permit continuation of the cooling after the engine has shut down are very desirable to prevent overheating of the oil. These precautions also aid in the retention of an oil film on moving parts so that sufficient lubrication is available when the engine is restarted. The circulation of the cooling water should be discontinued before engine parts are cooled below the temperature of the air in the engine, otherwise condensation will occur.

Fig. 2—Sludge resulting from piston carbonization shown in Fig. 1.

If heated much higher than 500 degrees, auto ignition or spontaneous combustion of some lubricants is apt to result, in fact, serious crankcase explosions have occurred immediately after shutdown due to oil mist coming in contact with the underside of hot pistons.

An example of underside carbon is shown in Figure 1, a result of a combination of high temperature and improper oil. The effect of this breakdown of oil is apparent from Figure 2, which represents the filter from the same engine. In this same case the rings were found in excellent condition.

In an engine the oil is agitated violently in the presence of excess air and conditions are ideal for oxidation of the lubricant. The results of comparable engine runs at different temperatures given in Table C illustrate the pronounced effect of oil temperature on oil condition.

Table C

INFLUENCE OF OIL TEMPERATURE ON SLUDGE FORMATION

Crankcase Temperature	Percent Solids in Oil
150	0.11
175	0.20
200	0.28

When boosting power output, increasing speeds, or reducing engine size, the designer must watch oil temperatures and provide additional cooling if possible. Where the increased cooling is not supplied and oil temperatures are raised, the oil will have to be drained more frequently.

OIL VISCOSITY

Temperature Effect

In lubrication practice higher speeds usually require lighter, less viscous oils. In the Diesel field the higher speeds, however, have been accompanied by higher temperatures which normally necessitate heavier or more viscous lubricants. Actual tests have demonstrated, however, that the increased pumpability and the reduced internal friction of the lighter oils results in cooler running bearings and crankcases. In one high speed Diesel the effect of viscosity on crankcase temperatures is as given in Table D:

Table D

EFFECT OF VISCOSITY ON OIL TEMPERATURE

SAE Number	Crankcase Temperature Degrees Fahr.
30	200
20	185
10	160

This and other confirming evidence has substantiated the statement long ago made by

Ricardo—"When oil of higher viscosity is used the friction is greatly increased at first but on account of the greater amount of energy dissipated in shearing the oil film, the heat flow is greater, the temperature is, therefore, higher, same body at 100 degrees Fahr. may differ somewhat in viscosity at 210 degrees Fahr., but as explained by Ricardo, the thinner oil will tend to run cooler so that actually in the engine the two oils will be of about the same viscosity.

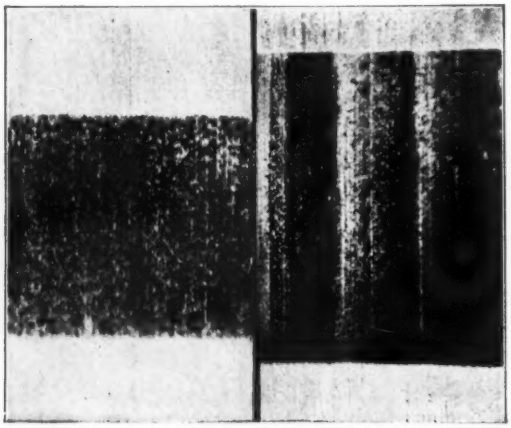


Fig. 3A—Appearance of Worn Areas of Piston-Ring-Iron Specimens (relatively high weight loss, but with ability to slough off wear products without surface mutilation).

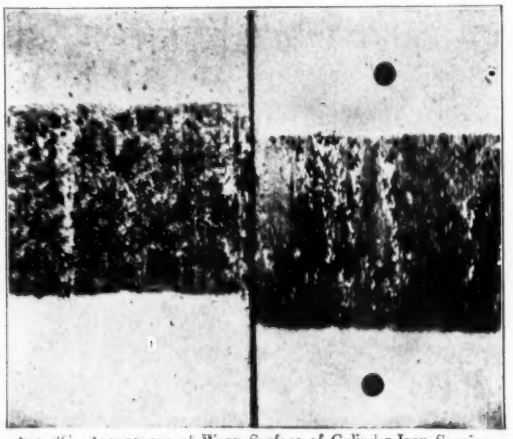


Fig. 3C—Appearance of Worn Surface of Cylinder-Iron Specimen. (Low weight loss but high susceptibility to scuffing).

Fig. 3B—Piston-ring-iron (fine grain) Photomicrograph (50x unetched).

Characteristics of Piston-ring-iron*:

1. Very fine graphite and sorbitic pearlite matrix of eutectoid composition.
2. High dry-wear values, based on weight loss only, but with good freedom from scuffing proclivities.
3. A granular surface tending to free itself of wear products, thus presenting a smooth unblemished contact face even under adverse loading.
4. Tendency toward glazing is less than in coarser-type irons, such as are often used for cylinders and liners.
5. Slight proneness to imbedding of abrasive matter so that lapping action is not present on the ring face.

Fig. 3D—Cylinder-iron (coarse grain) Photomicrograph (50x unetched).

Characteristics of Cylinder-iron*:

1. Coarse graphite and laminated pearlite matrix, generally near eutectoid composition.
2. Low dry-wear values based on the weight-loss method, but with proneness to scuffing.
3. Surface roughness or "flowability" indicated by character of friction surface. Wear products tend to adhere and glaze rather than slough away.
4. A "bruise-readily and heal-quickly" quality, probably a desirable feature if unit loading does not become too high.
5. Imbeddability, which may account for high abuse or lapping action to mating surfaces.

Courtesy American Hammered Piston Ring Division, Koppers Company

Fig. 3—*Piston Ring and Cylinder Iron Metallurgy* (*from ASME paper, June, 1939, "Wear of Diesel Engine Cylinders and Rings" by P. S. Lane).

with the result that after running some time, the reduction in viscosity due to the higher temperature nearly compensates for the higher initial viscosity." Two oils both having the

Pressure Effect

This tendency of certain oils to thin out more than others is also offset by the effect of pressure on viscosity. As illustrated in Tables

E and F, under pressures sufficient to cause bearing failure, the low V.I. oil which thins out more, due to increased temperature alone, is actually the more viscous in the engine, due to the influence of pressure.

Table E

EFFECT OF PRESSURE ON VISCOSITY

(From article by H. A. Everett, Penn State, in *S.A.E. Journal*—November 1937.)

Viscosity Index	103	20
Viscosity Centapoise at 210 degrees—atm. press.	9	8
Viscosity Centapoise at 210 degrees—4000 lbs./sq. in.	15	21

Table F

CENTAPOISE VISCOSITY FROM TABLE E CONVERTED TO THE MORE FAMILIAR SAYBOLT VISCOSITY

Viscosity Index	103	20
Viscosity Saybolt secs. at 210 degrees—atm. press.	62	54
Viscosity Saybolt secs. at 210 degrees—4000 lbs./sq. in.	86	109

Starting Requirement

The increased use of Diesels in cold weather has made the fact, that some oils become more viscous than others at low temperature, of importance when selecting crankcase oils for engines which must be started in cold, exposed locations. To provide easy starting a maximum viscosity of about 30,000 seconds at the starting temperature is required for some engines. To meet this condition, in cold weather, S.A.E. 10 and 20 oils are required and the viscosity-temperature relationship is therefore important in these grades. The S.A.E. 30 and 40 oils regardless of their viscosity-temperature relationship start the engine readily at the warmer temperatures for which they are recommended, therefore, the viscosity-temperature characteristics of these oils are not so important.

The trend seems to be rather definitely towards the use of lighter oils, as they lead to:

Cooler engines,

Easier cold weather starting,

Less friction — better fuel economy,

Easier purification.

The use of lighter oils has been made possible largely by improvements in design to overcome the inherent disadvantages of such oils which include:

Higher oil consumption,

Greater blow-by,

Greater possibility of wear at high temperatures,

More noise—less cushioning of worn parts.

PISTON RING AND CYLINDER LUBRICATION

The generally higher mean effective pressures and higher speeds which prevail in the modern Diesel produce greater pressure behind the rings and more frictional heat. As a result, ring and liner difficulties have increased. As long as a lubricant supplies a good oil film on the cylinder walls, it cannot be held responsible for wear and scoring difficulties and, except in special cases, the maintenance of a good oil film is not difficult. If inspection of the cylinders shows a good oil film, altering the lubrication is not apt to cure any wear or scoring which may be occurring.

Such ring and cylinder difficulties are usually caused by dust, liner scale, blowby, cold operation, improper break-in or improper machining

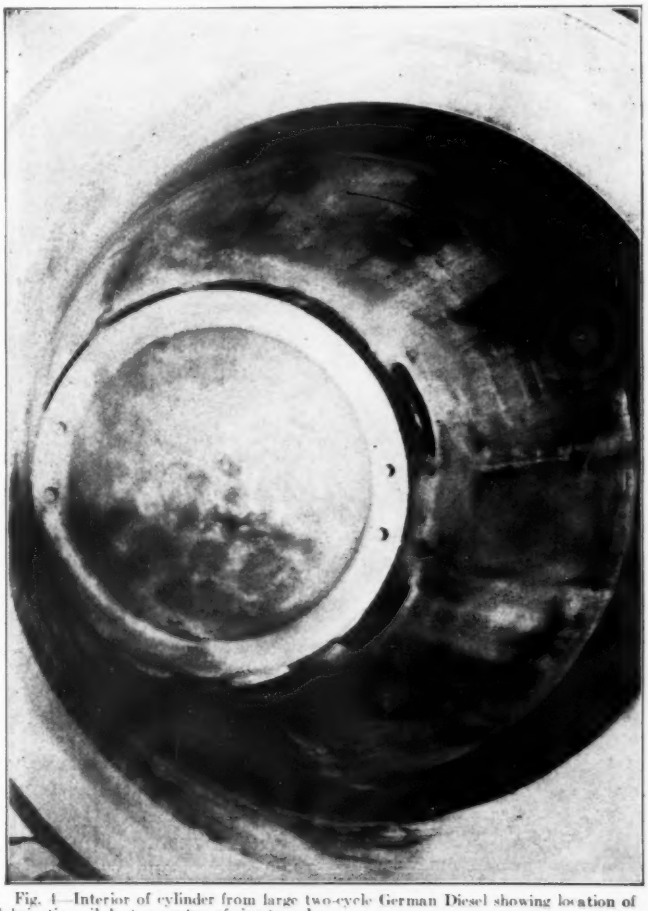


Fig. 4—Interior of cylinder from large two-cycle German Diesel showing location of lubricating oil ducts near top of ring travel.

but in some cases trouble persists when all these factors are ruled out—leaving it up to the designer and metallurgist. Much has been accomplished in improving ring design and in cylinder construction to obtain a good, perma-

nent ring fit. Ring and cylinder metals have been actively studied and the compatability of certain materials is now better understood.

As explained in Figure 3, cylinder liners are usually made from tough coarse grained iron

Fig. 5—Piston designed to prevent heat from piston head reaching rings. Heat is carried away by oil striking underside of piston, resulting in comparatively low ring temperatures and freedom from ring sticking.

which resists wear but at the expense of greater scoring tendency, while piston rings are often constructed from finer grain iron which does not score readily but is more prone to wear. Thus, when abusive conditions are present the ring is sacrificed to reduce wear of the more expensive liner.

Special treatment of both the running surfaces and the lubricating oil has been tried to reduce scuffing and wear during the run-in period while the rings are being mated to the liners. The betterment that can be effected with special oils is measurable but slight, compared to the pronounced improvement resulting from the special treatment of rings. Some ring coatings employ a soft bearing metal—others a mild abrasive action to prevent scuffing during the wearing-in period. Mild chemical treatments that reduce wear are also in use for the purpose of eliminating certain materials from the surface of the metal or improving its texture to better retain an oil film.

The two-cycle engine is becoming decidedly popular for certain applications even though under heavy duty conditions some difficulties have been encountered due to the tendency of cylinders to run dry. This condition is rather general and not confined to any one make. Although some oils appear able to withstand these operating conditions better than others, the engine designers have taken care of this situation more dependably by the proper location of the cylinder lubricator leads.

Originally in two-cycle engines the cylinder oil from the mechanical lubricator was injected below the ports. In this location the oil ducts were never uncovered and timed lubrication was unnecessary. This location prevented to some extent, excessive wear of the bridges between the ports. Not only are these bridges hard to lubricate due to the tendency of the oil to be blown off, but the rapid cooling of the bridge during the casting process promotes the formation of an iron structure which is more prone to wear.

With the advent of timed lubricators, cylinder oil feeds were often moved above the ports to eliminate the difficulty of getting the oil by the latter, but sufficiently near the bridges to prevent wear of these parts. In this location, however, the oil enters the cylinder a long way from the top of the ring travel where finally due to greater power output, temperatures may become excessive and cylinder and rings worn.

To eliminate this dry condition at the top of the cylinder, many foreign and some American two-cycle engines now introduce the oil, with a timed lubricator, near the top of the ring travel, as shown in Figure 4.

To the lubrication engineer, this new location seems most logical. The oil is fed to the cylinder at only a few points and must spread to the remainder of the cylinder rather quickly. Now an oil molecule has a natural tendency to always run away from a hot surface to a cooler area, regardless of the law of gravity. This tendency in most cases is fortunate since it aids in the spreading of the oil, but it is obvious that the oil should be injected at the hottest point of the surface. When oil is injected at the bottom part of the cylinder, the rings, in carrying the oil upward, must overcome the natural tendency of oil to keep away from hot areas. Oils which resist this tendency have been developed but it has been found that they frequently do not spread as well as other oils and do not relieve the ring wear problem when acute.

The dry condition noted is also relieved by certain materials used in special piston rings. It has long been realized that a piston ring must be able to withstand a certain amount of direct contact with the cylinder walls. A complete oil film would require machining accuracy which would reduce surface imperfections below the

microscopic thickness of the oil film. Even if such production accuracy were possible in machining large bores, the inevitable distortion would result in some metal-to-metal contact between rings and cylinders. To meet this condition, rings of good frictional characteristics have been developed. These special rings have been successfully used to overcome the lack of lubricant at the top of the ring travel.

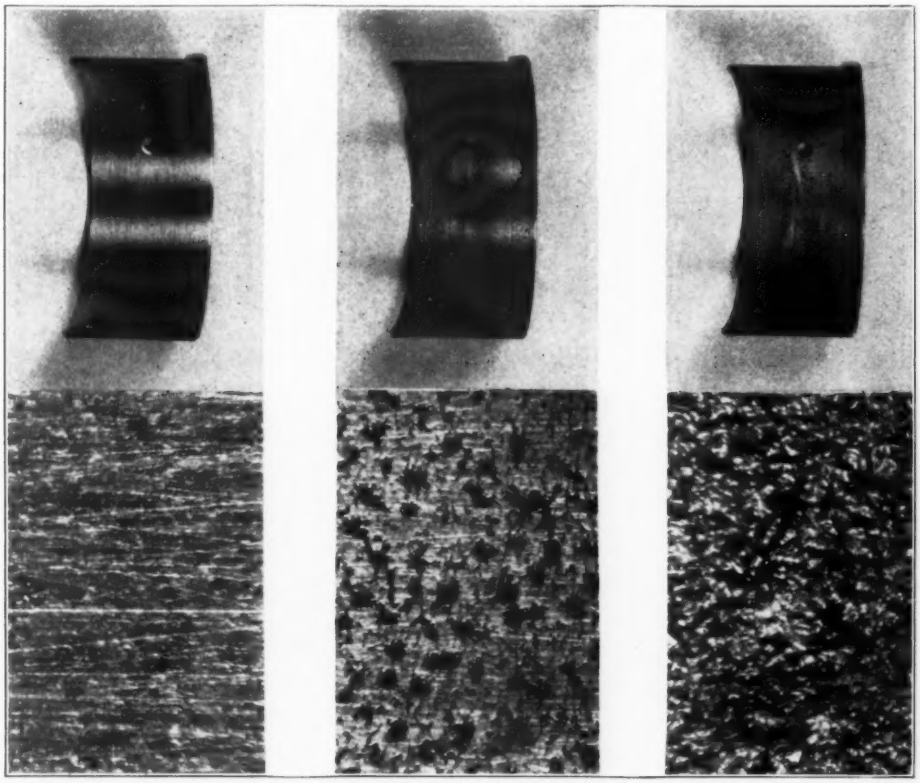


Fig. 6—Copper lead bearings and their photomicrographs. Left—Non-corroded bearing. Center—Oil corrosion, lead removed, copper unaffected. Right—Fuel corrosion, sulfurous acid attacks copper.

It appears that a dry cylinder condition can best be overcome by injecting the oil near the top of the stroke and by employing metals which have good wetability as well as oil film retention characteristics.

Ring-sticking has increased with engine output and the amount of heat which the rings must transfer to the cylinder walls. Much has been done by the designer to keep down the ring temperature and prevent ring sticking. An example is given in Figure 5.

It has been quite definitely established after years of experience that the temperatures in a Diesel are such that properly refined distillate oils leave less ring deposit than some other types of straight mineral oils. Special oils having a dispersion action have proved superior in this respect in certain engines but very often at the expense of other desirable characteristics.

BEARING LUBRICATION

The tensile strength of babbitt is greatly reduced at higher temperatures, dropping from around 9000 lbs. per square inch at 150 degrees Fahr., to about 4000 lbs. per square inch at 250 degrees Fahr.

As a result, high oil temperatures combined with greater loads and speed have caused many manufacturers to use copper-lead, cadmium-silver and other heavy duty composition bearings. The characteristics of such bearings are shown in Table G.

Table G

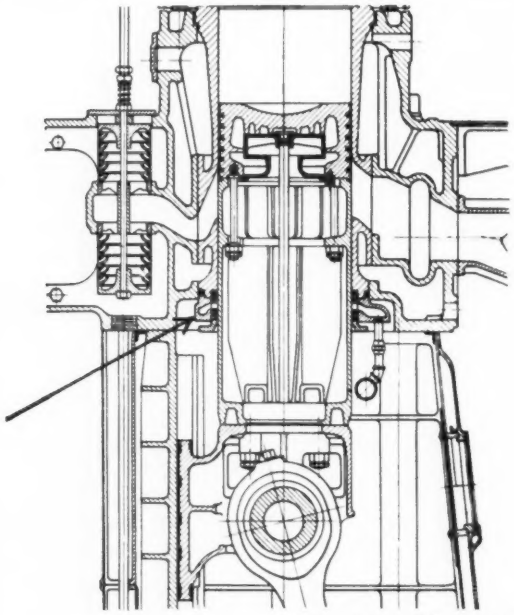
LOAD CAPACITIES AND OTHER CHARACTERISTICS OF BEARING METAL

(From paper by A. B. Willi—Federal Mogul Corp.—*Diesel Power*—August 1939.)

Description of Bearing Metal	Maximum Unit Pressure, Lb./sq. in.	Maximum Oil Reservoir Temp. Degrees Fahr.	Minimum Crankshaft Hardness Brinell	Affected by Corrosion
Tin Base Babbitt	1000	235	Not important	No
Lead Base Babbitt	1800	225	Not important	No
Cadmium-Silver	1800–3850	260	250	Yes*
Copper-Lead	1800+	260	300	Yes*

*Not likely if temperature is maintained as specified and proper lubricating oil is used.

It will be noted that the copper-lead and cadmium-silver bearings may be subject to oil corrosion. Some engines, too, have been found to require the plasticity of the calcium-hardened lead bearings which also are rather easily corroded.



Courtesy Nordberg Mfg. Company

Fig. 7—Crosshead type two-cycle Diesel with sludge pocket (indicated by arrow), in cylinder preventing fuel and oil residues from reaching crankcase.

The influence of the lubricating oil on corrosion of bearings is being intensively investigated at the present time. There is still much to be learned regarding this phenomenon but there are some points regarding straight mineral oils which seem to have been reasonably well established, i.e.;

New oil does not corrode bearings.

At high temperatures, above 270 degrees or thereabouts, some oils, as a result of a reaction with air, form oxidation products which dissolve lead from copper-lead and high lead bearings and cadmium from cadmium-silver bearings.

Maintaining a low oil temperature is the best safeguard against such corrosion although the overheating of a small portion of the oil may cause the formation of corrosive products in the oil even though the overall temperature is low.

The neutralization number which measures the organic acidity of an oil is no criterion of the corrosiveness of the oil to bearings.

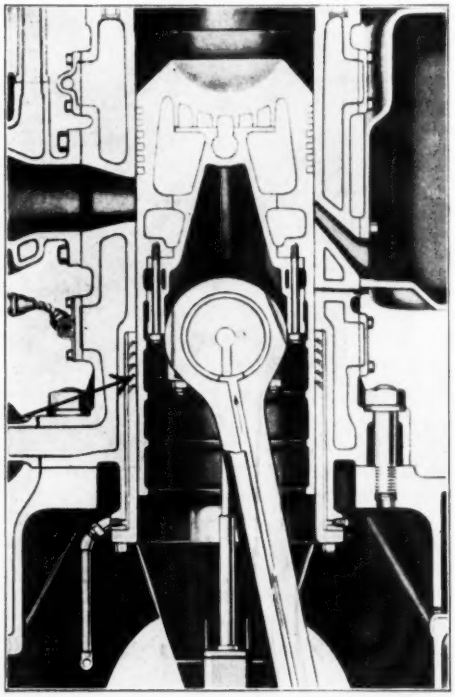
Certain metals promote, others inhibit corrosion. Iron, particularly when dissolved in the oil, greatly accelerates corrosion, therefore corrosion is most apt to occur in new "green" engines before iron surfaces become coated and when oil is contaminated with iron from initial wear. On the other hand, the presence of tin or indium in the bearing metal reduces its susceptibility to corrosion.

More frequent changing of the oil and thorough flushing of the engine is advisable where corrosion conditions exist. This prevents the building up of corrosive products to a concentration sufficient to cause trouble. It also keeps down the iron content of the oil.

Adequate crankcase ventilation removes some corrosive oil products and the tendency towards corrosion of bearings is averted.

Some copper-lead bearings are more easily corroded than others. Fine grain copper-lead bearings are better than coarse grain. The improper rate of cooling of the bearing after casting is said in some cases to cause segregation of the lead, resulting in a non-uniform bearing structure and greater susceptibility to corrosion.

The degree of oil purification is important. Certain purifiers reduce the corrosive tendency of an oil while others may remove corrosion inhibitors.



Courtesy Fairbanks-Morse & Co.

Fig. 8—Scraper rings and drain (indicated by arrow), for fuel and oil residues.

As illustrated in Fig. 6, materials other than oil oxidation products can cause bearing corrosion. Fine particles of dust, iron or carbon

imbedded in bearing metal frequently are mistaken as evidence of corrosion. Erosion is also mistaken for corrosion, particularly where soft metals are involved; in such cases erosion is evidenced by a circumferential ring of deteriorated metal starting at the point of entry of the abrasive material. Corrosion, on the other hand, is distinguished by a general pitted appearance over a more widespread area.

OIL RECONDITIONING

The changes brought about by weight reduction have necessitated improved methods of oil reconditioning due to greater contamination of the lubricant. The purification of oil in Diesels is made necessary to a large extent by the contamination of the lubricant in the crankcase by residual products of combustion of the fuel. A few engines are so designed that combustion takes place in the center of the combustion chamber and in such engines analyses of blow-by gas has revealed that they are made up largely of rather clean heated air. In many engines, however, the blow-by gases contain much soot from the fuel. In one large installation, for example, upon changing to a heavier, less combustible fuel the centrifuge deposits increased threefold.

Engine manufacturers have long realized the desirability of preventing contamination of the lubricating oil. Three methods of preventing fuel and lubricating oil decomposition products from reaching the crankcase are shown in Figures 7, 8 and 9.

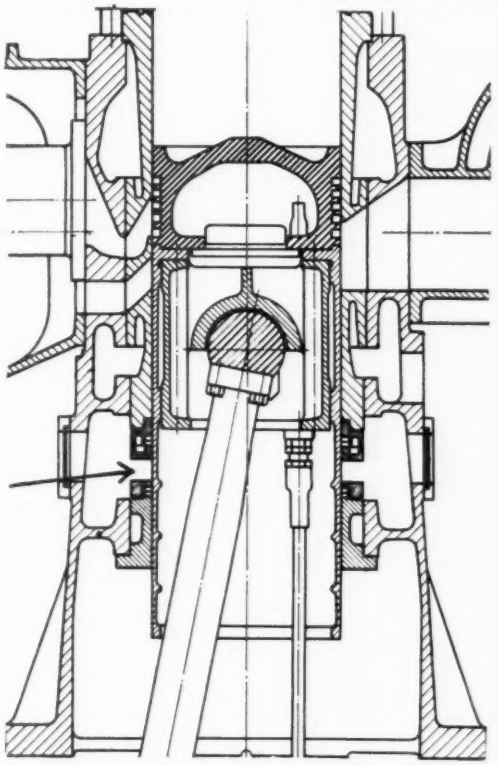
Higher speeds, supercharging and other factors have increased the amount of fuel burned while smaller engines have in some cases reduced the size of the oil sumps. Thus the fuel consumption/oil capacity ratio has increased as has oil contamination.

The adoption of solid injection may result in greater contamination of lubricating oil, although fuel consumption is usually improved due to the elimination of the bulky, heavy and power consuming air compressor. The greater contamination in solid injection engines occurs chiefly when burning fuels containing heavy tarry residual products which are not present in the light distillate fuels.

Using such heavy fuels it is not uncommon to find centrifuge deposits around .3 lb. per 1000 rated H.P. hours. Analysis has shown that a 1000 H.P. Diesel operating continuously in a year may throw out at the centrifuge about:

108 Gallons of good lubricating oil.
110 Gallons of water.
530 Pounds of carbon (fuel soot).
180 Pounds of tarry material (oxidized oil).
150 Pounds of minerals (dust, iron, etc.)

To provide satisfactory lubrication and prevent ring sticking and sludge formation in the engine the oil purification system must remove the solids as fast as they collect or the oil must be changed. Incidentally, there is more merit to frequent oil changing than is usually realized. Not only is a complete oil change the only way



Courtesy of Busch-Sulzer Bros. Engine Co.

Fig. 9—Sludge chamber (indicated by arrow), for collecting fuel and oil residues.

in which all contaminants can be removed from the system but an economic analysis of the cost of oil purification, where less than 1000 horsepower is installed, will show that the oil can be changed every 1000 hours at a cost less than the expense of many oil purifying devices.

Regardless of the type of oil purifier used, whether centrifuge, filter or reclaimer, the viscosity of the oil will gradually increase in service. Periodic analysis of used oil from a large stationary Diesel operating under severe conditions with a centrifuge are given in Table H.

Table H
USED OIL ANALYSIS
(Centrifuge)

Hours Service	Viscosity (SSU at 100 Degrees Fahr.)	Precipitation Number (solids)	Neutralization No. (oxidized oil)
0	800	0	0.05
2,100	860	0.1	0.4
4,900	900	0.2	0.4
8,400	910	0.3	0.6
10,500	920	0.2	0.7
14,000	1000	0.3	1.0

Periodic treatment of the oil in activated clay type purifiers likewise fails to prevent a gradual rise in viscosity as shown in Table I.

Table I

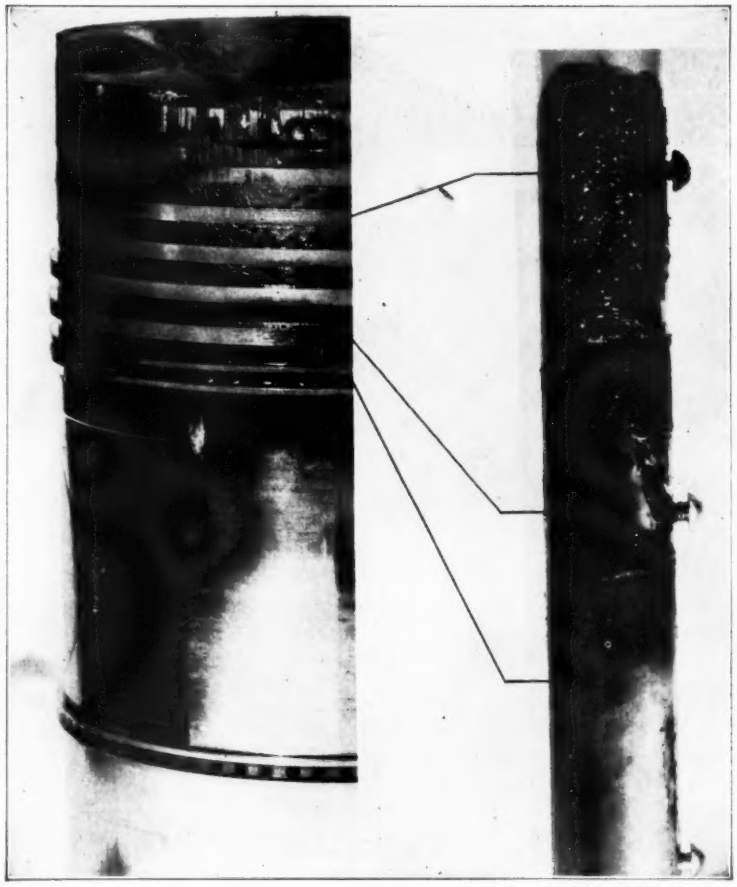
USED OIL ANALYSIS
(Activated Clay Purifier)

	New Oil	Used Oil	Reconditioned Oil
Viscosity SSU at 100 Degrees Fahr.	750	853	842
Neutralization Number	0.05	0.68	0.33
Precipitation Number	0	0.10	Trace
Final Boiling Point Degrees Fahr.	848	....	910

No commercial oil purification device brings the oil back to its original condition. To prevent this increase in viscosity it is becoming quite customary to use a lighter oil for make-up.

Efficient Centrifuge Operation

The increasing difficulty of keeping the oil clean in certain new types of Diesels has prompted a thorough study of the best method of operating the centrifuge to remove sediment from the oil as fast as it developed. The results of this investigation are tabulated in Table J.



Courtesy Caterpillar Tractor Co.

Fig. 10A—Correlation of lubricating oil deposits on piston and heated bar. Lines connect points of equal temperature. Oil used resists oxidation but does not evaporate cleanly when heated on hot plate as shown in Fig. 10B. Note stuck compression rings but clear oil rings.

Table J

EFFECT OF OPERATING CONDITIONS ON DEPOSIT REMOVED BY CENTRIFUGE

Centrifuge Operating Conditions		Centrifuge Deposit Pounds per Hour
Oil Temperature at Centrifuge	180 Degrees Fahr.	0.50
	160 Degrees Fahr.	0.34
	140 Degrees Fahr.	0.22
Viscosity SSU at 100 Degrees Fahr. of Used Oil	750 sec.	0.50
	800 sec.	0.48
	900 sec.	0.46
	1000 sec.	0.43
	1100 sec.	0.41
	1200 sec.	0.39
Oil Flow through Centrifuge—percent rated capacity	20	0.38
	40	0.50
	60	0.52
	80	0.50
	100	0.40
	110	0.30
Hours Centrifuge run before cleaning	2	0.73
	4	0.59
	6	0.49
	8	0.42
	10	0.40

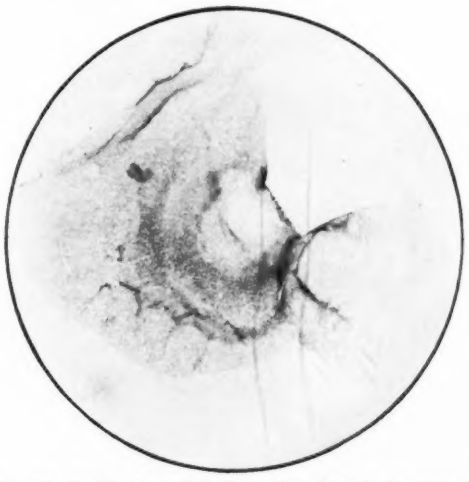
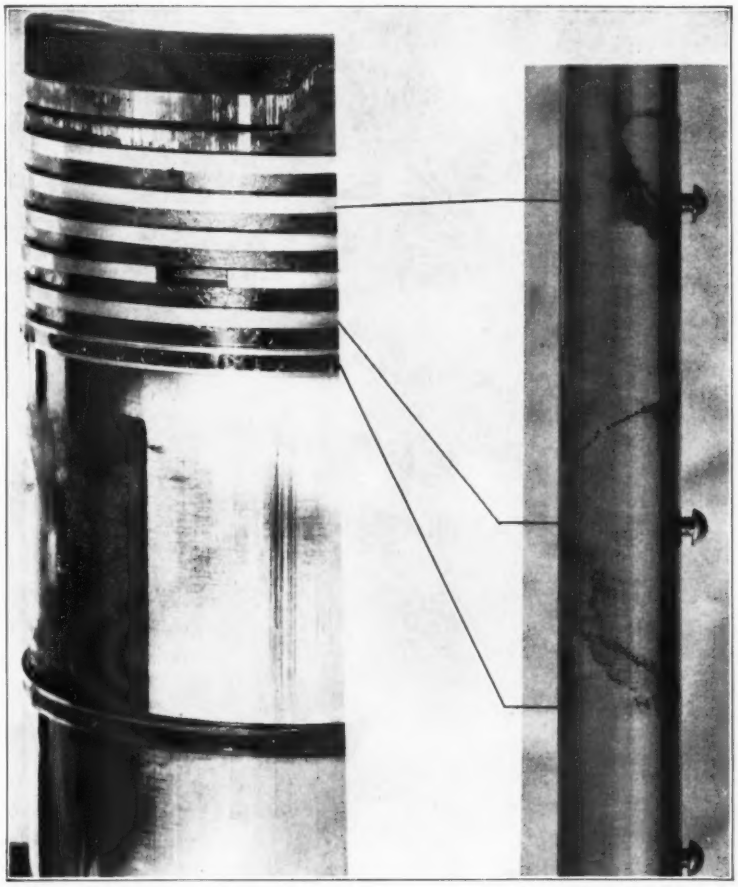


Fig. 10B—Residue from oil similar to that shown in Fig. 10A when heated on hot plate.

The data shown in Table J indicate that, if the condition of the oil is unsatisfactory, the



Courtesy Caterpillar Tractor Co.

Fig. 11A—Test similar to Fig. 10A but with an oil which oxidizes rather readily but evaporates cleanly when heated on a hot plate, as shown in Fig. 11B. Note free compression rings but clogged oil rings.

Fig. 11B—Residue from oil similar to that shown in Fig. 11A when heated on hot plate.

centrifuge can be brought up to maximum efficiency by adopting the following procedure:

1. Set the oil flow rate at 60 per cent. of the maximum capacity of the centrifuge for the particular oil and temperature.
2. Maintain oil temperature at centrifuge constant at 180 degrees Fahr.
3. Clean centrifuge bowl every six hours or oftener.
4. Operate centrifuge continuously.
5. Maintain original viscosity of the oil.

These rules apply generally although individual cases may require slightly different adjustment. When difficulties are being encountered the centrifuge deposit should be weighed as a measure of efficiency as adjustments are made.

SPECIALIZED LUBRICATION

It can almost be taken as an axiom in lubrication that the more improved and advanced the design and efficiency of a piece of machinery, the more difficult it is to lubricate and the more care must be exercised in selecting the proper oil. This is certainly true of internal combustion engines particularly the Diesel which has of late required considerable study by lubrication engineers.

A better knowledge of metals has contributed greatly to a gradual improvement of the Diesel since its origin over forty years ago. Improvements in metallurgy have been paralelled with advances in lubrication so that even in this relatively short period a highly efficient smooth running machine has been realized. The first Diesel undoubtedly was constructed with not more than three of four metals while today's Diesels contain literally dozens of different metals. Pistons, rings, cylinders, heads, frame, valves and bearings are among the many parts made with materials possessing the individual requirements necessary.

Similarly, each oil company originally had one Diesel engine oil while now several are necessary to provide best lubrication for the variety of design and operating conditions which exist.

Bearing metals have been subjected to particularly careful study. No one pure element has all the properties desired. Consequently, combinations of different metals are employed. For the same reason the oil refiner blends different hydrocarbons to obtain the characteristics desired in a Diesel lubricant. Small amounts of other metals are used to improve properties of a bearing, and lubricating oil likewise is improved by the additions of minute quantities of certain materials. Just as different proportions of metals are used to make up the bearing material, depending on the type of duty, so are the constituents of lubricating oil varied according to service requirements.

Carrying the comparison further: copper as an element in bearing metal has a high tensile strength and good load carrying capacity but is low in plasticity or conformability; therefore, scores readily. Of lead and tin the reverse is true, as they are low in tensile strength but superior in plasticity and anti-scoring properties. Therefore, where a high load carrying capacity bearing is required a high percentage of copper is frequently used in which case a sacrifice in anti-scoring qualities is made. In another design where scoring is apt to occur a higher percentage of tin or lead is used and load carrying ability sacrificed.

The same theory is followed in Diesel lubrication oil selection. For example, certain hydrocarbons are stable when heated to a high temperature in the absence of air but unstable at lower temperatures where an excess amount of air is present. The opposite is true of another type of hydrocarbon which resists oxidation but leaves a high carbon residue when heated to high temperatures. The first type has been found to be superior from a ring sticking standpoint but prone to form slightly more sludge. The performance of the latter type is reversed. Thus in selecting an oil for an engine inclined to ring sticking the thermal stable oil should be selected while if sludging of the oil ring was occurring the oxidation resistant oil should be used. This characteristic difference in base is well illustrated in Figures 10 and 11.

Just as there is no perfect bearing metal which possesses both the load carrying capacity of copper and the plasticity of lead, neither is there a perfect hydrocarbon having all the desirable properties. That one type of oil is best for all Diesels is a myth which is rapidly giving way even in advertising departments to the realization that certain oils are best for certain conditions.

There is nothing unique in this situation, in fact, in the selection of materials for all engineering work the designer seldom finds a perfect material possessing all the desirable attributes and is forced to compromise. For analogy, bearing materials have been discussed, other parts could as readily have been used. The piston ring manufacturer for example, can't find a perfect metal. So far a material having the best wearing characteristics does not have the other properties desirable in a piston ring.

Future research may develop such materials but it is an accepted principle in lubrication as well as in other types of engineering that the choice of materials varies with and is dependent upon the particular design and service conditions. There is certainly a wide variety of design and operating conditions in the Diesel industry; consequently, a variety of oils are required to lubricate each engine effectively.

Some of the duties which a Diesel lubricant may be called upon to perform are:

1. Prevent wear of cylinders, rings, pistons and bearings.
2. Keep rings free.
3. Maintain good oil film on cylinders.
4. Not corrode bearing metals.
5. Keep bearings and pistons cool.
6. Seal rings against blow-by.
7. Keep engine interior clean.
8. Not carbonize underside of piston.
9. Not deposit sludge on oil filter.
10. Keep oil lines and screen free from sludge.
11. Form no deposits in oil cooler.
12. Form no varnish on exposed metal surfaces.
13. Keep pistons clean.
14. Lubricate air compressor, gears and other auxiliaries.
15. Form no carbon in exhaust ports.
16. Separate readily from water.
17. Reclaim properly.
18. Centrifuge readily.
19. Lubricate for long periods without changing.
20. Provide easy starting at low temperatures.
21. Maintain low oil consumption.

In addition, a lubricant is frequently expected to alleviate piston seizure, ring scuffing, cylinder scoring, bearing cracking and other mechanical difficulties as well as valve sticking, contamination, dilution and other trouble resulting from poor combustion.

No oil can fulfill all these requirements perfectly. Fortunately, no single installation requires that the lubricant used be exceptional in all the respects listed; consequently, by proper oil selection, good lubrication can be assured.

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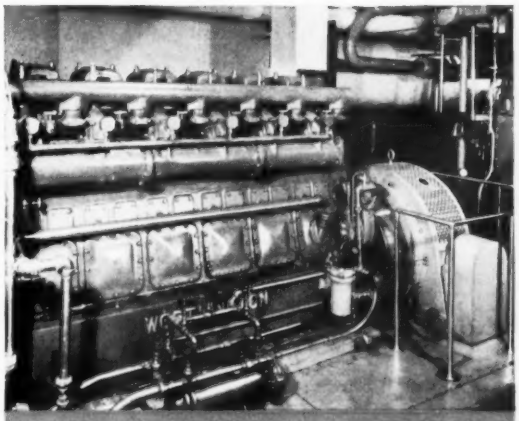
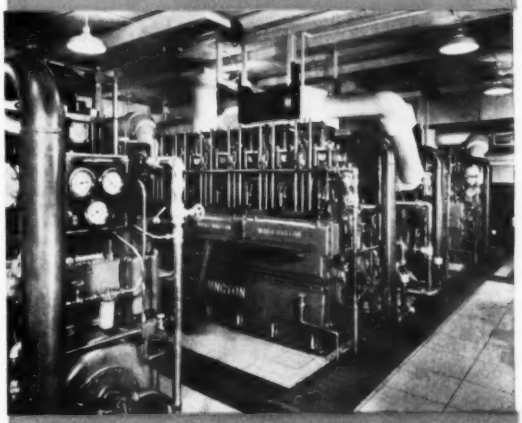
PISTON INSPECTION PERIODS EXTENDED

1,000 hrs.



FOUR OF THE 6 WORTHINGTON DIESELS in the A. I. Namm & Son plant. One 125 h. p., 310 r. p. m. unit and four 300 h. p., 400 r. p. m. engines were installed early in 1936. Another 150 h. p., 600 r. p. m. Worthington has been in service about a year. All are Texaco lubricated.



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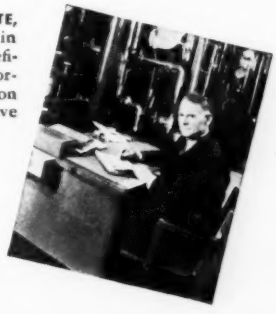

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GENERAL VIEW of Diesel power plant in Blooming Prairie, Minn. Spick - and - span, beautifully landscaped, it's a showplace.

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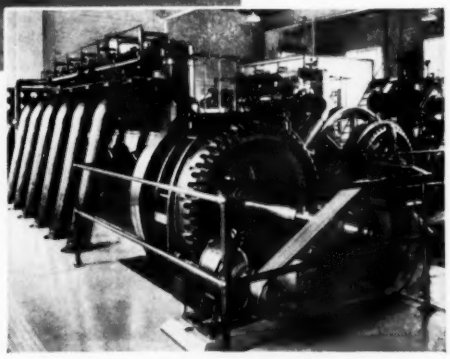
Below... All 3 Diesels in this showplace power plant are Texaco lubricated exclusively, since they first went into service.



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LOCATED IN BLOOMING PRAIRIE, MINN., the power plant illustrated here is visited by engineers of 7 surrounding States, interested in seeing Fairbanks-Morse Diesels at work in ideal surroundings.

Since this showplace was built, 7 years ago, its engines have been lubricated with Texaco Algol and Ursa Oils. A year ago, a 450 h.p. F-M Engine was added, and Texaco was again selected as the lubricant. "Cylinder wear very slight, never a bearing failure" reads the report.

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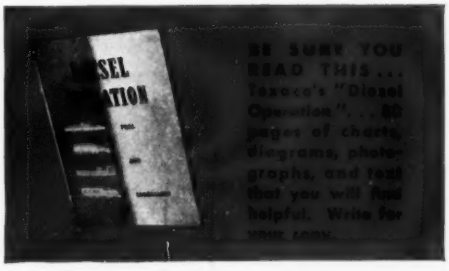

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